AIR FORCE REPORT NO.
SAMSO-TR-70-155

AEROSPACE REPORT NO.
TR-0066(5230-46)-2
(FORMERLY TR-0200(4230-46)-2)

Brightness Temperatures of the Quiet Sun and the New Moon at 3.3 - and 5.7-mm Wavelengths

Prepared by E. E. REBER
Electronics Research Laboratory

70 FEB 12

Laboratory Operations
THE AEROSPACE CORPORATION

Prepared for SPACE AND MISSILE SYSTEMS ORGANIZATION
AIR FORCE SYSTEMS COMMAND
LOS ANGELES AIR FORCE STATION
Los Angeles, California

THIS DOCUMENT HAS BEEN APPROVED FOR PUBLIC RELEASE AND SALE; ITS DISTRIBUTION IS UNLIMITED

38

PAGES ______
ARE
MISSING
IN
ORIGINAL
DOCUMENT

Air Force Report No.
SAMSO-TR-70-155

Aerospace Report No.
TR-0066(5230-46)-2
(Formerly TR-0200(4230-46)-2)

BRIGHTNESS TEMPERATURES OF THE QUIET SUN AND THE NEW MOON AT 3.3- AND 5.7-mm WAVELENGTHS

Prepared by

E. E. Reber
Electronics Research Laboratory

7Ø FEB 12

Laboratory Operations
THE AEROSPACE CORPORATION

Prepared for

SPACE AND MISSILE SYSTEMS ORGANIZATION
AIR FORCE SYSTEMS COMMAND
LOS ANGELES AIR FORCE STATION
Los Angeles, California

FOREWORD

This report is published by The Aerospace Corporation, El Segundo, California, under Air Force Contract F04701-69-C-0066.

This report, which documents research carried out from July 1967 through July 1969, was submitted for review and approval on 3 February 1970 to 1st Lt Jack S. Friedman, SMTAE.

The author is indebted to many of his colleagues in the Electronics Research Laboratory, and particularly to C. J. Carter, E. H. Erfurth, H. E. King, and J. M. Stacey for their counsel and assistance.

Approved

A. H. Silver
A. H. Silver, Director
Electronics Research Laboratory

Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

Jack S. Friedman
Jack S. Friedman, 1st Lt, USAF
Project Officer

ABSTRACT

Absolute brightness temperatures and brightness temperature ratios of the quiet sun and the center of the new moon were measured at the 3.3-mm wavelength and at several wavelengths in the 5.7-mm region. Radiometric maps of the sun and new moon are used to illustrate the problems associated with brightness temperature measurements of these sources. Measured quiet-sun/new-moon brightness temperature ratios and reported central brightness temperatures of the new moon in the millimeter wavelength region confirm the measured absolute brightness temperatures of the quiet sun.

Reported solar brightness temperatures in the 5.7- to 1.0-mm wavelength interval are tabulated and presented graphically as a function of frequency and wavelength. The regression-line equation computed for the reported measurements is given for estimating solar brightness temperatures at any wavelength in this interval and is solved for the wavelengths of the reported measurements.

CONTENTS

TABLES

FIGURES

I. INTRODUCTION

Absolute brightness temperatures and brightness temperature ratios of the quiet sun and the center of the new moon were measured at several millimeter wavelengths. The quiet-sun/new-moon brightness temperature ratios can be measured with greater accuracy than the absolute brightness temperatures because the ratios are not affected by the uncertainties of antenna main-beam efficiency and absolute temperature calibration. For the measurements reported here, the confidence intervals of the brightness temperature ratios are significantly better than the confidence intervals of the measured absolute brightness temperatures of the sun or the new moon. The high confidence intervals of the ratios make them particularly suited for monitoring solar-lunar temperature relationships and long-term solar temperature variations.

Brightness temperatures and brightness temperature ratios of the quiet sun and new moon were measured at the 3.3-mm wavelength and at several wavelengths in the 5.7-mm wavelength region. Absolute brightness temperatures of the quiet sun and the central region of the new moon are reported for the 3.3- and 5.7-mm wavelengths because only two independent systems were used for the measurements. Several solar brightness temperatures are reported for earlier independent measurements in the 5.7-mm wavelength region.

Measured quiet-sun/new-moon brightness temperature ratios and central brightness temperatures of the new moon are not only useful for monitoring solar brightness temperatures, but are also useful for comparing the absolute temperature calibration of different radio astronomy systems. However, the level of solar activity and the effects of antenna beam smoothing and sidelobe contributions must be accounted for prior to making any direct comparisons.

II. BRIGHTNESS TEMPERATURE VARIATIONS

The brightness temperature of any specific region on either the sun or the moon is both wavelength- and time-dependent. The brightness temperature of any particular lunar area is dependent upon the lunar latitude and varies periodically as a function of local phase. Central brightness temperatures of the new moon decrease very slowly with time, at an estimated rate of 0.14°K/hr at the 3.3-mm wavelength (Gary, Stacey and Drake, 1965). A radiometric map of the new moon at 3.3-mm, Fig. 1, shows a wide central region with small temperature differentials, a central brightness temperature of ~ 158°K, and the latitude dependence of the brightness temperature. At the 5.7-mm wavelength, the brightness temperatures of the new moon are ~ 10% higher than those at 3.3-mm, with a central value of ~ 175°K.

The solar brightness temperatures are not so well behaved, but are reasonably predictable for a given frequency and region on a day-to-day basis. Furthermore, their behavior at 5.7 mm is similar to that at 3.3 mm; radiometric maps of the sun (Figs. 2 and 3) made at both wavelengths on two successive days demonstrate this similarity. The mapping program, under digital computer control, automatically measures the brightness temperatures of a 21 by 21 array of data centered on the solar disk. The brightness temperatures are normalized to the central brightness temperature of the disk. The outline of the solar disk and temperature contour lines for 1-% temperature intervals have been superimposed. The mapping at 3.3 mm (Fig. 2) has better definition than the mapping at

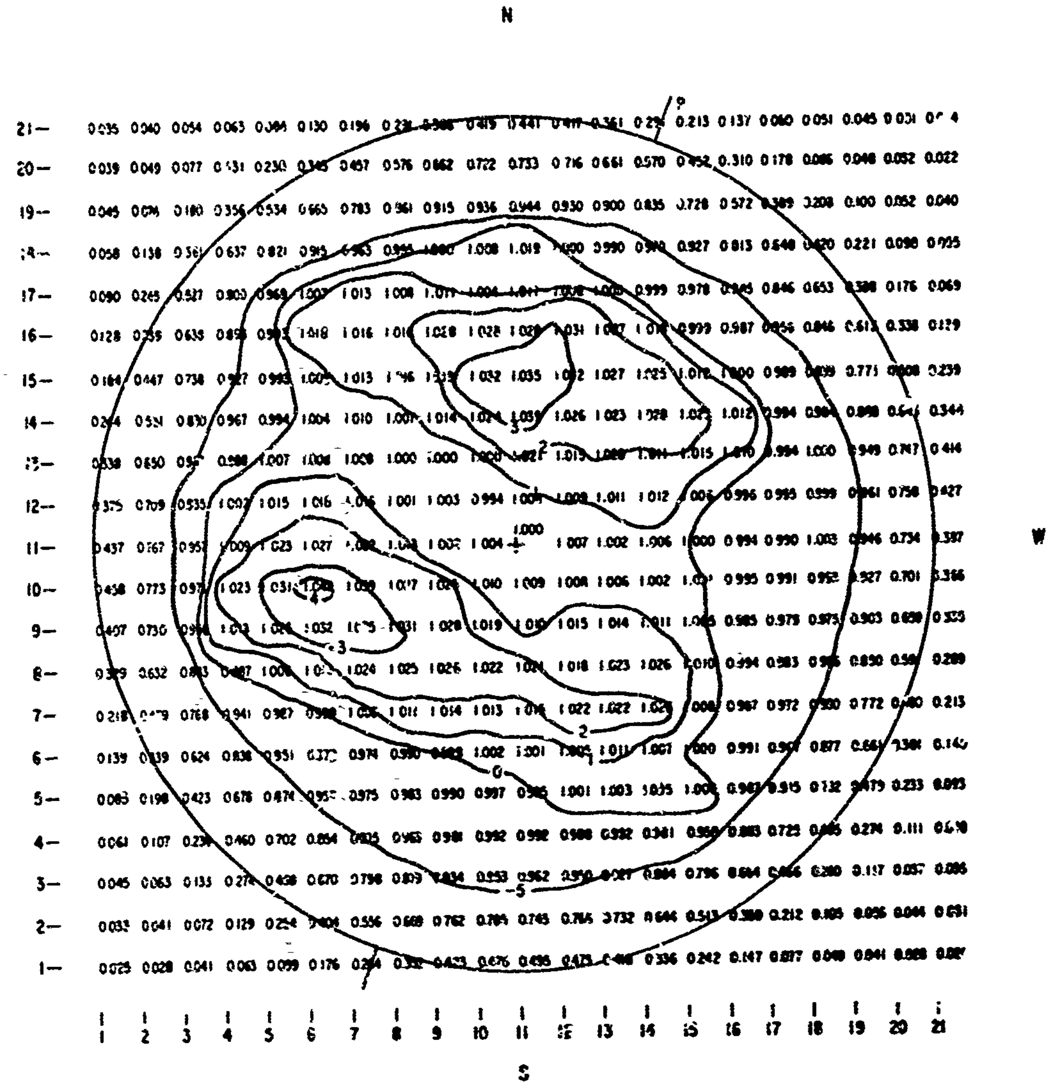


Fig. 3. Radiometric map of the sun at 5.7-mm wavelength on 19 May 1967

5.7 mm (Fig. 3) because of the sharper beamwidth, i.e., 2.78 arc-min compared to 4.32 arc-min, respectively.

A three-dimensional plotting technique (Mitchell, 1967) is used to present an isometric view (Fig. 4) of the 5.7-mm contour map of Fig. 3. Truncating and increasing the scale factor results in the view presented in the upper right corner of Fig. 4. Similar truncated three-dimensional sun maps at 3.3 and 5.7 mm, for two successive days (18 and 19 May 1967), are presented in Fig. 5. These maps show the similarity of solar activity at the two wavelengths. The differences between the maps for the same day are mainly attributable to higher resolution of the antenna at 3.3 mm and better noise performance of the 3.3-mm radiometer. The brightness temperatures varied from the central value by 7% at 3.3 mm and 4% at 5.7 mm, at beamwidths of 2.78 and 4.32 arc-min, respectively, on 18 May 1967. The notable difference between the maps from one day to the the next, especially evident in the 3.3-mm maps, is caused by the rotation of the sun. Although solar brightness temperatures normally vary by several percent across the disk at these antenna beamwidths with occasional flares of much greater intensity, quiet regions can often be tracked across the sun for periods of days.

Absolute solar brightness temperatures and quiet-sun/new-moon brightness temperature ratios measured with very narrow beamwidth antennas are prone to wide scatter caused by solar activity. Furthermore, measurements made at the same wavelength with different antenna beamwidths may have significant differences caused by antenna beam smoothing.

These effects, which can be minimized by careful selection of quiet solar regions for measurement, are one of the major sources of differences in measured solar brightness temperatures at millimeter wavelengths.

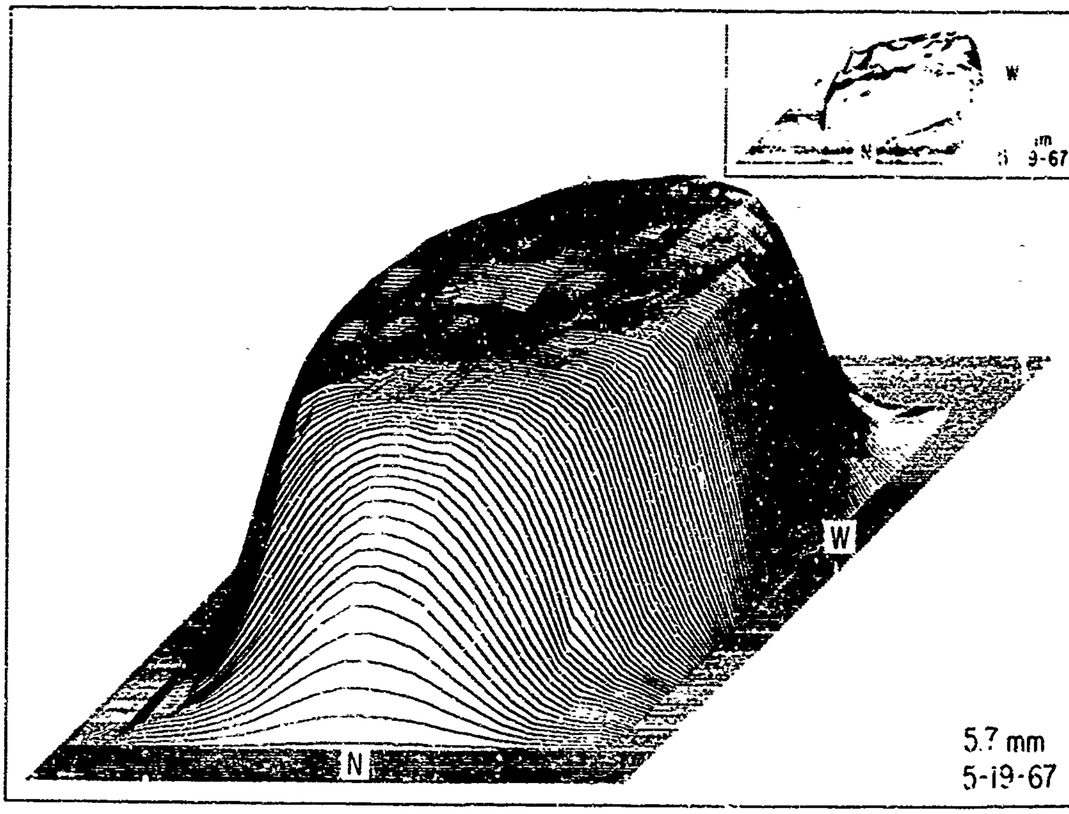


Fig. 4. Three-dimensional plot of solar brightness temperatures at 5.7-mm wavelength (Inset: truncated and amplified view)

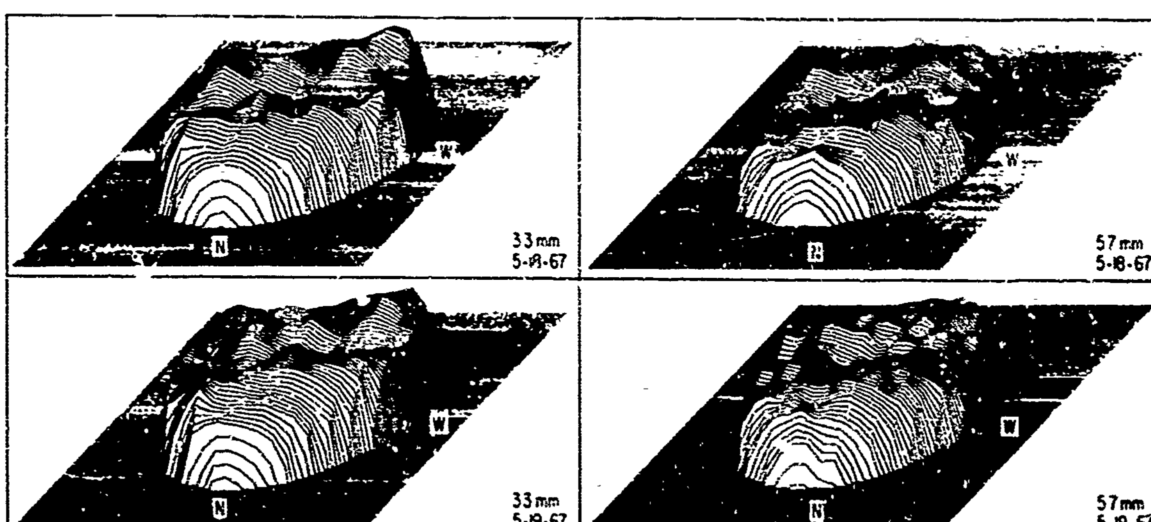


Fig. 5. Truncated three-dimensional plots of solar brightness temperatures for two successive days at 3.3- and 5.7-mm wavelengths

III. BRIGHTNESS TEMPERATURE MEASUREMENTS

A. QUIET-SUN/NEW-MOON MEASUREMENTS

The quiet-sun/new-moon brightness temperature measurements were made on The Aerospace Corporation's 4.57-m antenna at El Segundo, California, which has a theoretical half-power beamwidth of 4.32 arc-min at 5.7 mm and a measured half-power beamwidth of 2.78 arc-min at 3.3 mm. The antenna has Cassegrainian optics with feed horns and sub-reflector optimized for 3.2 mm (94 GHz) operation, resulting in computed antenna main-beam efficiencies to the solar limbs of 77 ± 2% at 3.3 mm and 39 ± 6% at 5.7 mm. The computed 3.3-mm radiation pattern shows the first sidelobe to be 26 dB below the peak of the main beam at 4.3 arc-min. At 5.7 mm, the first sidelobe is down 15 dB at 7.2 arc-min and the second sidelobe, 20 dB at 16 arc-min. Further, the sidelobe levels fall below 40 dB for either wavelength at 1.25 deg from the antenna axis. Therefore, sidelobe contributions from both the sun and polar darkening of the new moon are estimated to affect the lunar measurements by less than 1%.

Brightness temperatures were measured for a quiet region of the sun and the center of the new moon in July and August, 1967 and in April, May, and August, 1968. The angular separation between the solar and lunar centers did not exceed 7.5 deg during the measurements except for the 6 July 1967 measurement, which was 12 deg. The quiet status of the observed solar region was determined by inspection of 3.3-mm radioheliograms.

Measurements were made of two calibration temperature references,

PRECEDING PAGE BLANK

the blank sky, and the selected quiet solar region; a similar series of measurements were made for the central region of the new moon. This procedure of alternately measuring the apparent brightness temperature of the quiet sun and new moon was repeated over a wide range of zenith angles. An integration time of 15 sec was used for the 3.3-mm measurements, and 30 sec for the 5.7-mm measurements. The measurements were made with switched comparison load, superheterodyne radiometers whose measured linearities are within 1% over their temperature range and whose minimum detectable input temperatures ΔT for a 0.25-Hz postcorrelation bandwidth are $1^{o}K$ for 3.3 mm and $6^{o}K$ for 5.7mm.

Solar and lunar brightness temperatures versus air mass for two sets of observations are plotted in Figs. 6 and 7 for 3.3- and 5.7-mm wavelengths, respectively. The absolute brightness temperatures for the quiet sun and the new moon measured at 3.3- and 5.7-mm wavelengths on 7 July 1967 and 27 May 1968, respectively, are:

Wavelength, mm	$T_{Sun} \pm 1\sigma$, ^{o}K	$T_{Moon} \pm 1\sigma$, ^{o}K	Moon's Mean Phase, deg
3.3	6619 ± 420	160.8 ± 10.2	3.3
5.7	6964 ± 529	175.1 ± 20.5	5.6

The 1-σ confidence interval error budget includes an uncertainty of ±2% at 3.3 mm and ± 6% at 5.7 mm for the antenna main beam efficiency, ± 6% at 3.3 mm and ± [illegible].5% at 5.7 mm for temperature calibration, and the uncertainty of the zero intercept of the regression line for each set of data.

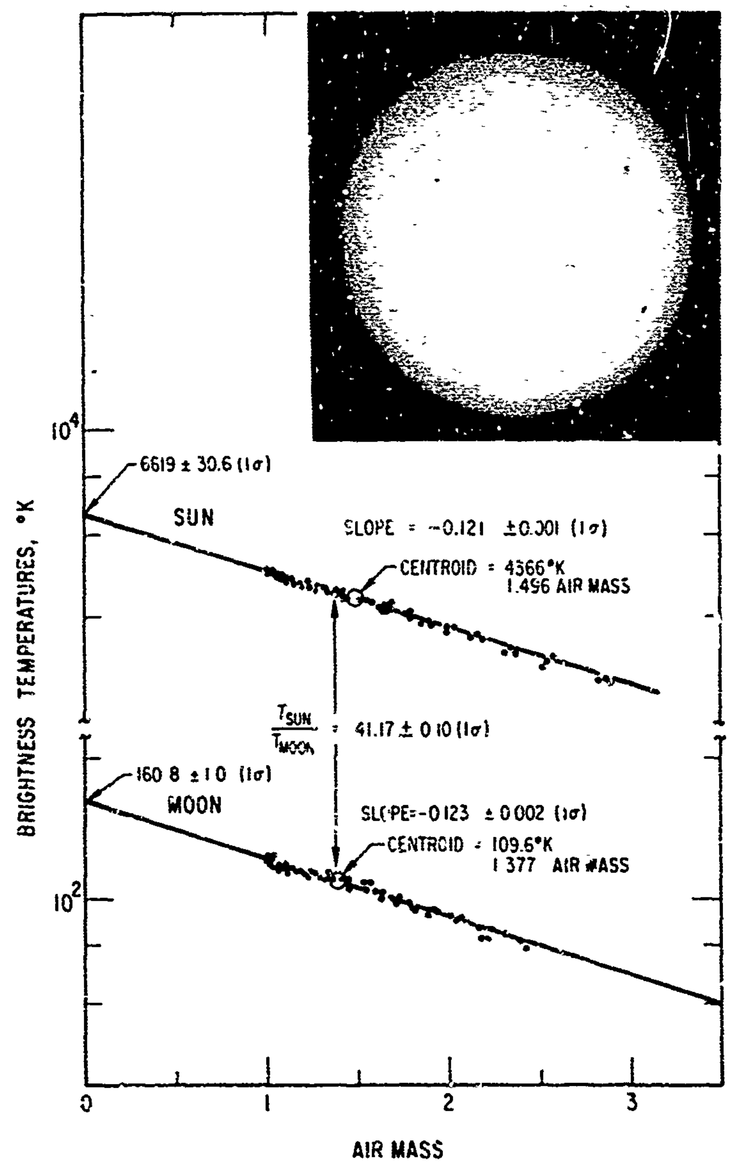


Fig. 6. Posttransit solar and lunar brightness temperatures vs air mass at 3.3-mm wavelength, 7 July 1967

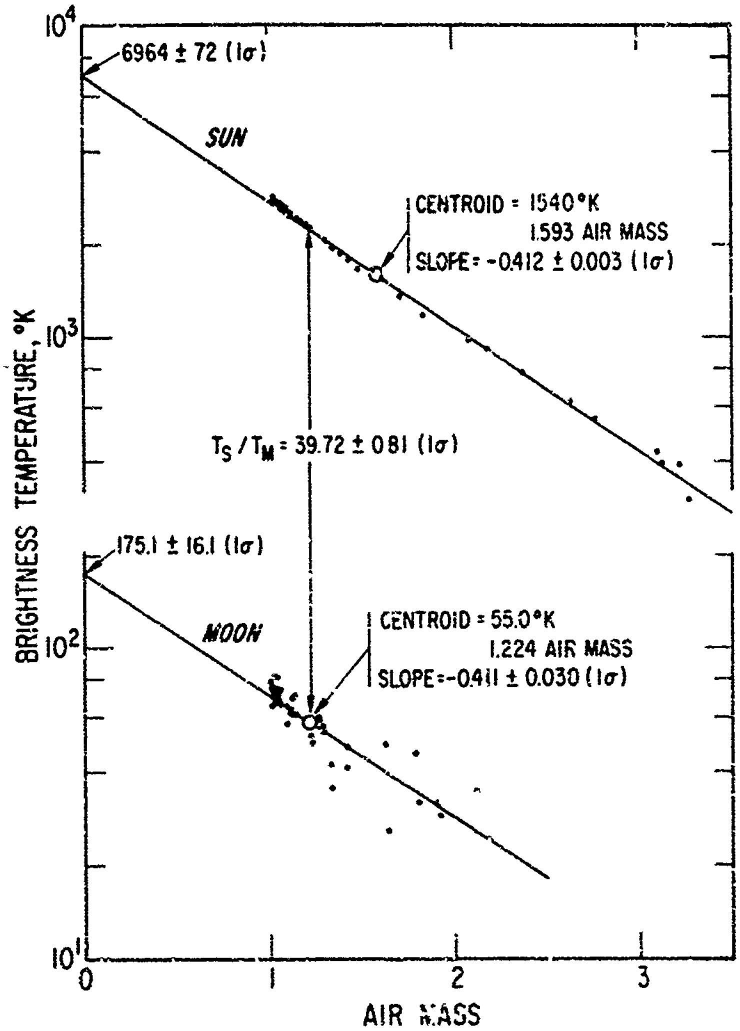


Fig. 7. Posttransit solar and lunar brightness temperatures vs air mass at 5.7-mm wavelength, 27 May 1968

B. SOLAR MEASUREMENTS

Extensive measurements of apparent solar brightness temperature versus air mass for a wide range of zenith angles were made from an aircraft at 6.1, 9.1, and 12.2 km. The measurements were made with a 0.61-m-diam, Cassegrainian-type antenna with a measured 39 arc-min beamwidth at 55 GHz and a half-power solid angle beam efficiency to the limbs of the sun of 28 to 33% over the frequency range from 53.4 to 56.4 GHz. The radiometer was continuously tunable over the frequency range with a 1-sec ΔT of $5^{\circ}K$ at midband to $8^{\circ}K$ at the band edges. Antenna pointing was controlled by an automatic optical sun-tracker with manually aided positioning. Measurements were made of two calibration temperature references, the blank sky and the solar disk. After compensating for the transmissivity of the radome and atmospheric emission effects, a linear analysis of the logarithm of excess antenna temperature versus air mass (Hardie, 1962) was done for each wavelength at each altitude.

The weighted mean of the intercept values of 45 sets of brightness temperatures versus air mass measurements, obtained over a wide range of zenith angles at three different altitudes and 22 different frequencies, is

$$T_{solar\ disk} = 6950 \pm 520\ (1\sigma)\ ^{\circ}K$$

at the median frequency of 54.5 GHz.

Brightness temperatures of quiet solar regions were measured with the flight radiometer installed on The Aerospace Corporation's 4.57-m antenna. The weighted mean of the intercept values of six sets of brightness temperature versus air mass measurements at 53.5 GHz is

$$T_{sun} = 6900 \pm 600 \ (1\sigma) \ ^{o}K$$

After modification and subsequent absolute temperature calibration, the flight radiometer was reinstalled on the 4.57-m antenna to make a series of solar measurements at 53.4 GHz. The weighted mean of the intercept values of six sets of brightness temperature versus air mass measurements for quiet solar regions at 53.4 GHz is

$$T_{sun} = 6750 \pm 600 \ (1\sigma) \ ^{o}K$$

IV. BRIGHTNESS TEMPERATURE RATIOS

Quiet-sun/new-moon brightness temperature ratios are measured with greater accuracy than the absolute brightness temperatures of either source because the ratios are not affected by the uncertainties of antenna main-beam efficiency and the absolute temperature calibration of the system.

The quiet-sun/new-moon brightness temperature ratios in Table I were computed from the regression line values at the air mass ordinate that passes through the centroid of the lunar regression line. These ratios exhibit lower statistical uncertainties than the ratios computed from the zero air mass intercepts of the solar and lunar regression lines (Crow et al., 1960). The small statistical uncertainties of the ratios are mainly attributable to atmospheric fluctuations and radiometer noise. The differences in the ratios at the 3.3-mm wavelength are probably caused by temperature differences of the quiet solar regions. The brightness temperatures across the solar disk at these wavelengths and antenna beamwidths often vary 5 to 10% from the central brightness temperature. Cooling of the lunar surface causes a small phase effect, which is estimated to be < 0.6% for the worst case. Sidelobe contributions, from both the sun and the polar darkening of the lunar disk, are estimated to affect the lunar measurements by < 1%.

TABLE I

SUMMARY OF BRIGHTNESS TEMPERATURE RATIO MEASUREMENTS

Date	Transit	Moon's Mean Phase, deg	Wavelength, mm	Number of Measurements		Temperature Ratio ± (1σ) Confidence Interval[a]
				Sun	Moon	
7 July 1967	Post	3.3	3.3	87	82	41.17 ± 0.10
23 August 1968	Pre	358.6	3.3	35	34	41.61 ± 0.10
	Post	0.7	3.3	91	89	42.38 ± 0.12
6 July 1967	Post	350.4	5.6	63	55	39.84 ± 1.39
27 April 1968	Post	3.2	5.8	80	65	40.47 ± 0.91
27 May 1968	Post	5.6	5.7	38	48	39.72 ± 0.81

[a]The average temperature ratio ± (1σ) confidence interval at 3.3 mm is 4 .72 ± 0.10.

V. ESTIMATED SOLAR BRIGHTNESS TEMPERATURES

The absolute brightness temperature of the quiet sun at millimeter wavelengths can be estimated with very low statistical uncertainties (1) from measured quiet-sun/new-moon brightness temperature ratios and reported brightness temperatures of the new moon and (2) from reported solar brightness temperatures in the millimeter wavelength region.

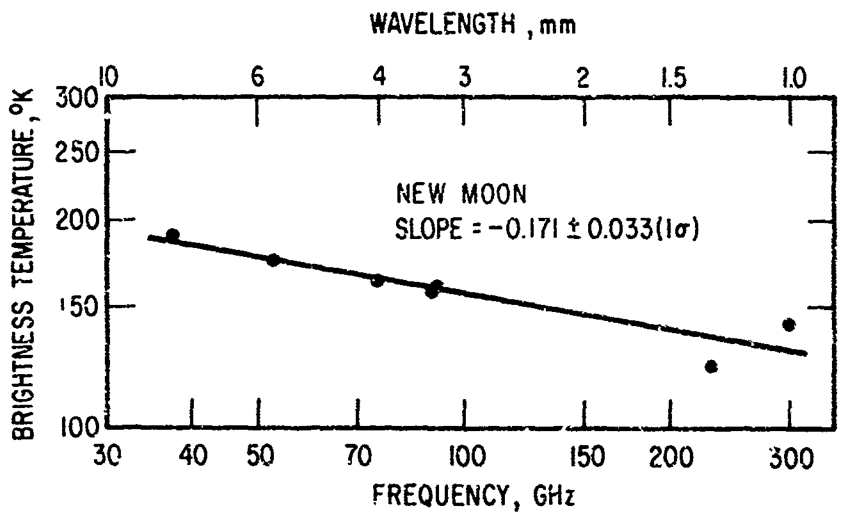
The first method depends upon the accuracy of the quiet-sun/new-moon brightness temperature ratio measurement, the accuracy of numerous independent measurements of the absolute central brightness temperature of the new moon, and the assumption of a linear regression of the lunar brightness temperatures with frequency in the millimeter wavelength region. The second method depends upon the accuracy of the many independent brightness temperature measurements of the sun at millimeter wavelengths and upon the assumption of a linear regression of solar brightness temperatures in the 50- to 300-GHz spectrum as indicated by the Van de Hulst model of Shimabukuro and Stacey (1965).

Reported central brightness temperatures of the new moon are summarized in Table II and graphed as a function of frequency and wavelength in Fig. 8. The linear regression of Fig. 8 gives equal weight to each measurement. The linear fit over the millimeter wavelength interval is justified by the distribution of the data and by the thermal radiation mechanism of the lunar surface at new moon. The equations of the regression line are

TABLE II

NEW-MOON BRIGHTNESS TEMPERATURE SUMMARY

Wavelength, mm	Frequency, GHz	Central Brightness Temperature, °K	Source
1.0	300.0	139	Low and Davidson (1965)
1.3	231.0	123 ± 18	Fedoseyev (1963)
3.3	90.4	158	Gary, Stacey, and Drake (1965)
3.3	91.0	161 ± 10 (1σ)	Reber (1969) This report
4.0	75.0	163 ± 24	Kislyakov (1961)
5.7	52.4	175 ± 21 (1σ)	Reber (1969) This report
8.0	37.5	189	Salomonovich and Losovskii (1962)



FREQ.,GHz	T_b,°K		(1σ) CONFIDENCE INTERVAL,°K
	MEASURED	CALCUATED	
37.5	189	185	7.4
52.4	175	175	5.5
75.0	163	164	4.1
90.4	158	159	3.7
91.0	161	159	3.7
231	123	138	5.1
300	139	130	5.8

Fig. 8. Reported central brightness temperatures of the new moon at millimeter wavelengths

$$T_{b\ (\text{New Moon})} = 345\ F_{\text{GHz}}^{-0.171}$$

$$T_{b\ (\text{New Moon})} = 130\ \lambda_{\text{mm}}^{0.171}$$

The solutions of the regression line equation at the wavelength of each of the reported measurements and the 1-σ confidence intervals of the computed values are tabulated in Fig. 8.

The absolute brightness temperatures of quiet regions near the center of the solar disk, using the quiet-sun/new-moon ratios and the estimated central brightness temperature of the new moon for a calibration reference temperature, are presented in Table III. The absolute brightness temperatures at 3.3- and 5.7-mm wavelengths are

$$T_{b\ (\text{Quiet Sun})} = 6567 \pm 152\ (1\sigma)\ ^{\circ}\text{K at } 3.3\text{ mm}$$

$$T_{b\ (\text{Quiet Sun})} = 6955 \pm 260\ (1\sigma)\ ^{\circ}\text{K at } 5.7\text{ mm}$$

These results are in good statistical agreement with the absolute solar brightness temperatures measured at the 3.3- and 5.7-mm wavelengths and are not affected by the uncertainties of our antenna main-beam efficiency and absolute temperature calibration.

Reported solar brightness temperature measurements in the 5.7- to 1.0-mm wavelength region are tabulated in Table IV and graphed as a function of frequency and wavelength in Fig. 9. A linear regression line, the 1-σ confidence interval of the ordinate to the regression line, and the standard error of estimate are shown in Fig. 9. Each measurement is equally weighted. The justification for a linear fit over this wavelength interval,

TABLE III

SOLAR BRIGHTNESS TEMPERATURES FROM QUIET-SUN/NEW-MOON RATIOS

Frequency, GHz	Wavelength, mm	Measured T_S/T_M Ratio ± (1σ)	T_{Moon} ± (1σ), °K	T_{Sun} ± (1σ), °K
51.44	5.83	40.47 ± 0.91	175.8 ± 5.6	7115 ± 277
52.38	5.73	39.72 ± 0.81	175.1 ± 5.5	6955 ± 260
53.40	5.62	39.84 ± 1.39	174.7 ± 5.4	6960 ± 324
90.4	3.32	41.17 ± 0.10	159.5 ± 3.7	6567 ± 152
90.4	3.32	41.61 ± 0.10	159.5 ± 3.7	6637 ± 154
90.4	3.32	42.38 ± 0.12	159.5 ± 3.7	6760 ± 157

TABLE IV

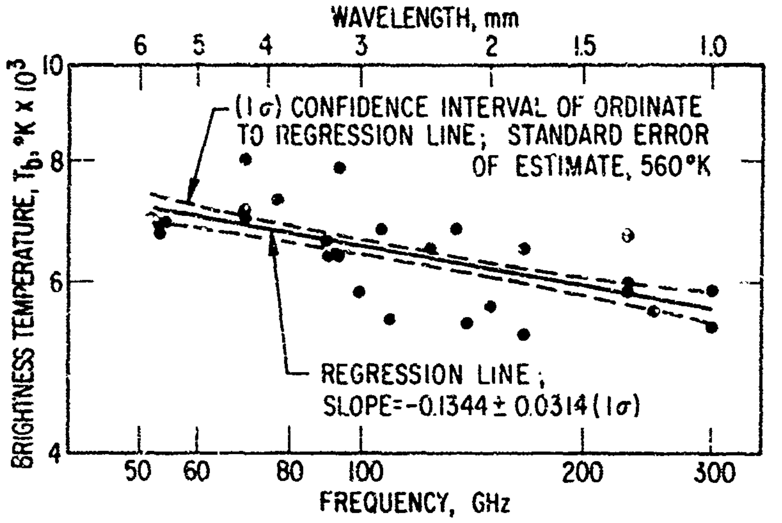
SOLAR BRIGHTNESS TEMPERATURE SUMMARY

Wavelength, mm	Frequency, GHz	Central Brightness Temperature, °K	Temperature Tolerance, °K	Source
1.0	300.0	5900	± 500	Low and Davidson (1965)
1.0	300.0	5400	± 350	Low and Gillespie (1968)
1.2	250.0	5600	± 400	Bastin et al. (1964)
1.3	231.0	5900	± 400	Bastin et al. (1964)
1.3	231.0	6000	± 500	Bastin et al. (1964)
1.3	231.0	6700	± 700	Fedoseyev (1963)
1.8	167.0	5300	± 700	Gorokhov, Dryagin, and Fedoseyev (1962)
1.8	167.0	6500	± [illegible]	Naumov (1963)
2.0	150.0	5670	± 230	Wort (1962)
2.15	140.0	5433	± 500	Tolbert and Straiton (1961)
2.2	136.0	6800	± 400	Bastin et al. (1964)
2.4	125.0	6500	± 400	Bastin et al. (1964)
2.73	110.0	5500	± 715	Tolbert and Straiton (1961)
2.8	107.0	6800	± 500	Bastin et al. (1964)

TABLE IV

SOLAR BRIGHTNESS TEMPERATURE SUMMARY (Concluded)

Wavelength, mm	Frequency, GHz	Central Brightness Temperature, °K	Temperature Tolerance, °K	Source
3.0	100.0	5870	± 950	Tolbert and Straiton (1961)
3.2	94.0	6402	± 215 (1σ)	Simon (1965)
3.2	94.0	7860	± 500	Tolbert, Straiton, and Walker (1962)
3.3	91.0	6375	± 574	Rusch, Slobin, and Stelzreid (1966)
3.31	90.5	6619	± 547 (1σ)	Reber (1969) This report
3.9	77.5	7300	± 200	Kislyakov and Plechkov (1964)
4.3	70.0	7000	± 700	Coates (1958)
4.3	70.0	7100	± 200	Tolbert et al. (1962)
4.3	70.0	8000	± 700	Kislyakov and Plechkov (1961)
5.50	54.5	6950	± 600 (1σ)	Reber (1969) This report
5.61	53.5	6750	± 600 (1σ)	Reber (1969) This report
5.62	53.4	6900	± 600 (1σ)	Reber (1969) This report
5.73	52.4	6964	± 529 (1σ)	Reber (1969) This report



FREQ. GHz	T_b, °K		(1σ) Confidence Interval, °K
	Measured	Calculated	
52.4	6964	7128	217
53.4	6900	7108	212
53.5	6750	7106	212
54.5	6950	7066	208
70.0	7000	6854	159
70.0	7300	6854	159
70.0	8000	6854	159
77.5	7300	6761	143
90.5	6619	6621	123
91.0	6375	6616	123
94.0	6402	6588	120
94.0	7860	6588	120
100.0	5870	6533	115
107.0	6800	6474	111
110.0	5500	6450	110
125.0	6500	6340	108
136.0	6800	6269	111
140.0	5433	6244	112
150.0	5670	6187	116
167.0	5300	6098	125
167.0	6500	6098	125
231.0	5900	5838	162
231.0	6000	5838	162
231.0	6700	5838	162
250.0	5600	5776	172
300.0	5900	5636	196
300.0	5400	5636	196

Fig. 9. Reported solar brightness temperatures in the 5.7- to 1.0-mm wavelength region

although arbitrary, is based on the linearity of the Van de Hulst theoretical model of Shimabukuro and Stacey (1968) for the 50- to 300-GHz region and by the distribution of the plotted measurements. The equation of the regression line is

$$T_{b(S)} = 12,130\ F_{GHz}^{-0.1344}\ ^{o}K$$

$$T_{b(S)} = 5637\ \lambda_{mm}^{0.1344}\ ^{o}K$$

from which we compute

$$T_{b(S)} = 6621 \pm 123\ (1\sigma)\ ,\ ^{o}K \text{ at } 3.3 \text{ mm}$$

$$T_{b(S)} = 7128 \pm 217\ (1\sigma)\ ,\ ^{o}K \text{ at } 5.7 \text{ mm}$$

These results are in good statistical agreement with the measured absolute brightness temperatures at 3.3 and 5.7 mm. Computed values of the regression line and the 1-σ confidence intervals of the ordinate to the regression line for the frequencies of the measured data are given in Fig. 9.

VI. CONCLUSIONS

The measured absolute central brightness temperatures of the new moon at the 3.3- and 5.7-mm wavelengths are in good agreement with values estimated from reported central brightness temperatures in the millimeter wavelength region. The measured absolute brightness temperatures of the quiet sun at the 3.3- and 5.7-mm wavelengths are in good agreement with (1) values estimated from reported solar brightness temperatures in the 5.7- to 1.0-mm wavelength region and (2) values estimated from the quiet-sun/new-moon ratios and reported central brightness temperatures of the new moon.

The brightness temperature ratios of the quiet sun and the central region of the new moon are measured with significantly greater accuracy than the absolute brightness temperatures of either source because systematic errors are minimized. Uncertainties of antenna main-beam efficiency and absolute temperature calibration and changes in atmospheric attenuation during the measurements have virtually no effect on the ratios. Therefore, absolute solar brightness temperatures can be determined with high confidence from the measured quiet-sun/new-moon brightness temperature ratios by using the central brightness temperature of the new moon as a calibration reference temperature.

REFERENCES

Bastin, J. A., Gear, A. E., Jones, G. O., Smith, H. J., and Wright, P. J. 1964, Proc. Roy. Soc., A278, 543.

Coates, R. J. 1958, Proc. IRE, 46, 122.

Crow, E. L., Davis, F. A., Maxfield, M. W. 1960, Statistics Manual, (New York: Dover Publications, Inc.) pp 152-167.

Fedoseyev, L. I. 1963, Izv. Vysshikh Uchebn. Zavedenii, Radiofiz., 6, 655.

Gary, B., Stacey, J., and Drake, F. D. 1965, Astrophys. J. Supplement Series, 108, XII, 239.

Gorokhov, N. A., Dryagin, Yu. A., and Fedoseyev, L. I. 1962, Isv. Vysshikh Uchebn, Zavedenii, Radiofiz., 5, 413.

Hardie, R. H. 1962, Photoelectric reductions. In "Astronomical Techniques" (W. A. Hiltner, ed.), (Chicago, Illinois: Univ. of Chicago Press), p. 179.

Kislyakov, A. G. 1961, Izv. Vysshikh Uchebn. Zavedenii, Radiofiz., 7 46.

Kislyakov, A. G. and Plechkov, V. M. 1964, Izv. Vysshikh Uchebn. Zavedenii, Radiofiz., 7, 46.

Kraus, J. D. 1966, Radio Astronomy, (New York: McGraw-Hill Book Co.), p. 73.

Low, F. J., and Davidson, A. W. 1965, Astrophys. J., 143, 1278.

Low, F. J., and Gillespie, C. M. 1968, 128th AAS Meeting.

PRECEDING PAGE BLANK

Mitchell, R. L. 1967, A Computerized 3-D Plotting Program, TR-1001(2230-46)-9 (Calif.: The Aerospace Corp.).

Naumov, A. I. 1963, News of Higher Educational Institutions. Ministry of Higher and Secondary Specialized Education, USSR, Radiophysics Series VI, 1. 12. (A translation of Ivestiya VUz Radiofizika, 6, (4) 1963).

Rusch, W. V., Slobin. S. D., and Stelzreid, C. T. 1966, Millimeter Wave Radiometry for Radio Astronomy, Final Rept. USCEE 183. (Calif.: Univ. of Southern Calif.).

Salomonovich, A. E. and Losovskii, B. Ya. 1962, Astr. Zh., 39, 1074.

Shimabukuro, F. I., and Stacey, J. M. 1968, Astrophys. J., 152, 777.

Simon, M. 1965, Astrophys. J., 141, 1513.

Tolbert, C. W., and Straiton, A. W. 1961, Astrophys. J., 134, 91.

Tolbert, C. W., Straiton, A. W., and Walker, T. A. 1962, The Investigation of Solar Emission and the Attenuation and Emission of the Earth's Atmosphere at the Frequencies of 69.75 and 94.0 KMCS, Rept. 6-45, (Texas: Univ. of Texas, Elec. Engr. Res. Lab.).

Wort, D. J. H. 1962, Nature, 195, 1288.

UNCLASSIFIED
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) The Aerospace Corporation El Segundo, California	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b GROUP

3 REPORT TITLE

BRIGHTNESS TEMPERATURES OF THE QUIET SUN AND THE NEW MOON AT 3.3- AND 5.7-MM WAVELENGTHS

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

5 AUTHOR(S) (Last name, first name, initial)

Reber, Earl E.

6 REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
70 FEB 12	31	19

8a CONTRACT OR GRANT NO. AF-04701-69-C-0066 b. PROJECT NO c. d	9a ORIGINATOR'S REPORT NUMBER(S) TR-0066(5230-46)-2 (Formerly TR-0200(4230-46)-2) 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) SAMSO-TR-70-155

10 AVAILABILITY/LIMITATION NOTICES

This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Space and Missile Systems Organization Air Force Systems Command Los Angeles, California

13 ABSTRACT

Absolute brightness temperatures and brightness temperature ratios of the quiet sun and the center of the new moon were measured at the 3.3-mm wavelength and at several wavelengths in the 5.7-mm region. Radiometric maps of the sun and new moon are used to illustrate the problems associated with brightness temperature measurements of these sources. Measured quiet-sun/new-moon brightness temperature ratios and reported central brightness temperatures of the new moon in the millimeter wavelength region confirm the measured absolute brightness temperatures of the quiet sun.

Reported solar brightness temperatures in the 5.7- to 1.0-mm wavelength interval are tabulated and presented graphically as a function of frequency and wavelength. The regression-line equation computed for the reported measurements is given for estimating solar brightness temperatures at any wavelength in this interval and is solved for the wavelengths of the reported measurements.

DD FORM 1473 (FACSIMILE)

UNCLASSIFIED
Security Classification

UNCLASSIFIED
Security Classification

14.

KEY WORDS

Brightness-Temperature Ratios
Brightness Temperatures
Lunar Brightness Temperature
Millimeter Wavelengths
Radiometric Maps
Solar Brightness Temperature
Temperature References

Abstract (Continued)

UNCLASSIFIED
Security Classification